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THE INTEGRATION OF THE DISCIPLINES

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INTRODUCTION

IN PREPARING STUDENTS FOR THE ACTIVITY CALLED LIVING, THOSE WHO DEVELOP THE CURRICULA FOR THE SCHOOLS RECOGNIZE THAT DIFFERENT ASPECTS OF LIFE MAY BE DEALT WITH IN RELATIVELY SEPARATE COURSES OF INSTRUCTION. Thus the schools teach courses in mathematics and science, language, art, music, drama, and automobile driving. Two broad types of schooling seem to be present in most curricula: science and humanities. These two types of courses correspond to two kinds of life activity: technological manipulation of the material world, and value-oriented axiological aspects of life where action is directed according to notions of what is good or beautiful or ethical. Some subjects, for example the content of courses in the "social sciences," include both scientific and axiological aspects; thus, in studying history we ask what happened and why (science), and whether that which happened was good or how we ought to behave today in view of what happened in the past (axiology).

Some educators believe that the subject area divisions are quite artificial. On this view, life is a unified activity which requires simultaneous or inter-related action in both the scientific and axiological spheres. The disciplines or school subjects are studies of limited aspects of life. Educators who hold this view advocate the integration of the disciplines. By this they mean that the school subjects should be taught in such a way as to convey to the student the cross-relevance and cross-fertilization of the subjects he studies. The integration of the disciplines involves curriculum planning and teaching methods designed to make clear the unification in life (or the possibility of such unification) of the limited aspects of life studied in school subjects.

If the integrated teaching of the subject areas is possible, there must in fact be an integration of these subject areas—if the scientific and axiological subjects in the curriculum are capable of being taught in a way which integrates them into a meaningful unified approach to life, it must in fact be true that science and axiology share common structures, methods, or objects of inquiry.

The purpose of this paper is to explore whether there are in fact any such integrating factors which are common to both science and axiology. I shall try to show that metaphysical inquiry provides such a unifying bond. Since those who study axiological subjects usually offer less resistance to metaphysics than do the scientists (indeed, some philosophers build value theories openly and directly based on metaphysical foundations), I shall concentrate in this paper on studying the relationship between science and metaphysics.

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The distinction between science and metaphysics is simply this—science is the study of empirical observations; metaphysics is the inquiry into the ultimate nature of Reality, including the study of how such inquiry is to be conducted properly. This distinction will be clarified throughout the paper, particularly in section one.

I hope to show that, although science and metaphysics sometimes consciously exclude each other from consideration, they are in fact close relatives engaged in a family squabble. Metaphysics is essential in science, in ways which will be made clear. Finally, I shall claim that metaphysics is a bridge between science and axiology. The existence of this bond means that the integration of the disciplines is possible, and the study of the bond may help us understand and teach the disciplines in an integrated manner, thereby providing a unified world view.

The first two sections of this paper are devoted to a discussion of the nature of scientific knowledge and method. Sections three and four describe the nature of mathematics and its role in science. Because science deals with empirical observations while mathematics is the a priori study of logical symbolism, we might expect that science and mathematics have radically different structures and methods—yet, we shall see that there is a remarkable unity and harmony between these two disciplines. The purposes of the first four sections of this paper are two-fold: (1) to study the nature of science and mathematics in order to discover how metaphysics is related to these disciplines; (2) to perform an actual integration of these two disciplines in order to demonstrate what is meant by "the integration of the disciplines" and in order to suggest a method for performing integrations between disciplines generally. Section five draws upon the previous four sections to comment specifically upon the relationship between metaphysics and science; in addition, some hints are given which indicate possible directions toward the integration of science and axiology on a metaphysical basis.

It would seem appropriate to interject a brief explanation concerning the footnotes in this paper. The issues dealt with in this paper have been debated for centuries by hundreds of authors, and I know no fair way of representing all the pro and con writers adequately; furthermore, I am not an expert on the history of the philosophy of science, nor do I claim exhaustive knowledge of the positions which have been taken or who has taken them. The views presented are my own; some points have undoubtedly been made by others without my knowledge, and other points have been consciously borrowed. The footnotes are intended to give credit in those instances where I have borrowed directly from the work of someone else.

I. The Nature of Scientific Knowledge

Scientific "knowledge" consists entirely of two kinds of objects: (1) facts, (2) theory-like constructs based upon facts.

(1) As Eddington has indicated,[1] the empirical basis of science consists of pointer readings—nothing more. These pointer readings are quantified reports of empirical experience—they are measurements which describe the inter-relationship between an event in the physical world and a device which records or measures that event.

[1]Arthur S. Eddington, *The Nature of the Physical World*, Chapter 12.

A closer examination of the character of pointer readings will disclose the source of the division between science and metaphysics. The interaction between a measuring device and the rest of the physical world is simply a fact of nature, in the same way as a collision between two billiard balls is a fact of nature. The distinction between measuring devices and ordinary billiard balls is to be found in the special uses we make of measuring devices. The difference is that human beings design measuring devices in such a way that the position of a pointer can be interpreted as indicating the truth of a human description of the world. Thus, we observe opposite the tip of an arrow a number on a scale, and conclude that the weight of an object is ten grams. The arrow and the scale over which it passes are connected with other physical objects in such a way that we claim that the position of the arrowhead on the scale tells us the weight of objects placed on top of our measuring device.

As mentioned before, the interaction between objects and measuring devices is a simple fact of nature. However, our conclusions based on the pointer readings are not facts of nature—they are human interpretations. Saying that (1) we see an arrow pointing to ten, differs remarkably from saying that (2) the weight of some object *is* ten grams. Both statements are subject to error; however, the first statement is a report of a sense perception while the second statement claims to represent a true condition of the real world. Without haggling over the meanings of "true" and "real," the difference should be clear.

The objects dealt with by science are the reports of pointer readings; thus, science deals with statements of the first type. Statements of the second type are typically made by scientists, but if pushed to an explanation of what they mean, the scientists will resort to statements of the first type. Thus arises a sharp distinction between science and metaphysics—the statements of science are reports of pointer readings, while the statements of metaphysics are claims about truth and reality in the objective world. Some philosophers of science make the division complete by relegating theories about the "true" nature of the "real" world to metaphysics, using the term "metaphysical speculation" to label the ideas thereby excommunicated from scientific deliberation.

Such philosophers of science defend this excommunication in a most reasonable way. A typical defense might run something like this:

> "What do you mean when you say that scientists do not make true statements about reality? Scientists investigate what happens, and they take special care to be sure their reports are both accurate and objective. Anyone can check the validity of scientific statements by performing appropriate experiments; thus, science, like democracy, is open to all who care to participate. Furthermore, scientists are careful to talk about facts, as you have indicated, and the facts are there for everyone to see."

To which we reply:

> "Certainly the facts are there for all to see. But in seeing the facts we see them only as we are able to see them, and we interpret them only as we are able to understand them. Our interpretations of the facts may very well differ from the truth. The essential point is that human nature may impose certain limitations upon our ability to understand the facts, which limitations may invariably distort our view of reality. On what basis do you claim both that there are no such limitations and that science actually does report the 'true' facts of the 'real' world?"

To which they reply:

> "Your discussion about absolute limitations to human powers of interpretation is pointless. (1) If there were such limitations on knowledge they would, by their very nature, remain forever unknown to us; hence, it is pointless to ask about what we can never know. (2) If there is a Reality beyond human knowability, why worry about it? If such Reality affects our knowledge in ways we can know, then we shall know these influences; if not, then such Reality will never give us cause for concern. (3) Your claims cannot be publicly tested—nobody can ever know whether they are true or false, by their very definition. Hence, your claims are dishonest. (4) Science reports and measures facts. Your claims, if true, do not report the kind of facts amenable to the methods of science. Hence, science cannot concern itself with your claims—your claims are metaphysical speculations."

To which we reply:

> "Thank you for clarifying our case. As you have shown, science is limited to pointer readings and their interpretations. Nothing else can be studied by science, and discussions about topics beyond the reach of pointer readings and their empirically testable interpretations are excommunicated as metaphysical speculation."

We shall return to these considerations later. For the present we shall merely observe that the nature of scientific knowledge, as outlined so far, gives us cause to worry about the narrowness of the scientific view of the world. We shall see later that this narrowness may hold back the progress of science. What is more important for the purposes of this paper, we shall observe that this narrowness, if maintained, may actually eliminate any possibility of integrating the disciplines into a unified world view acceptable to all the disciplines.

(2) It will be recalled from the opening sentence of this section that, in addition to dealing with facts, science deals with theory-like constructs based upon facts. Aside from simple interpretations of the pointer readings (such as the interpretation that an object weighs ten grams), scientists build theory-like constructs, which are attempts to classify the facts of science. These constructs are man-made edifices whose purpose is to provide frameworks of simplification and generalizations so that the facts may be better understood in the context of their inter-relationships.

Laws and explanations are nothing more than classifications of facts into generalized statements which are ultimately reducible to assertions of the form "x is y." Thus, a law is a statement such as "all apples, when released, fall to the ground." Given the observation that some particular apple has fallen to the ground, we desire an explanation. In this case, the explanation is the conjunction of two statements: (1) "all apples, when released, fall to the ground"; (2) "this is an apple which was released." The logical conclusion, "this apple fell to the ground," is the observation whose explanation is the conjunction of general law (1) and initial condition or observation of fact (2).

I do not wish to engage in the disputes among philosophers of science concerning the exact nature of laws and explanations. My point is simply this: all theory-like constructs are classifications of facts, and all such constructs provide logical or verbal frameworks in which statements representing observed facts are listed as logical deductions.

Clearly, theory-like constructs are different in character from reports of pointer readings. It will be noted that laws and explanations, discussed so far, classify reports of events which occurred in the past. With some fairness it may be said that laws and explanations are man's attempts to understand what happened. If man desires to control the future he will be interested in making predictions. Without becoming involved in nasty disputes, we may say, again with some fairness, that predictions are statements to the effect that the laws and explanations, established on evidence from the past, apply to the future. We shall recall the character of laws, explanations, and predictions in a subsequent section of this paper.

This section is entitled "The Nature of Scientific Knowledge," and it yet remains to identify what it is that science calls knowledge. When used in the strong sense, we say that knowledge entails truth (in the sense of correspondence to reality), belief, certainty, and good evidence. Thus, when we say in the strong sense that person X knows that proposition p holds, we mean all of these: (1) p is true, (2) X believes that p is true, (3) X is certain that p is true (there can be no doubt in X's mind), (4) X's belief is based on good evidence.

The discussion about pointer readings and metaphysics shows that in science no claim can be made to truth—at least, no claim can be made that we know for certain that our statements are true. The history of science shows that our concepts about the world have radically changed, and hence we remain uncertain about our present concepts since the advance of science may yet produce further change. The lack of certainty in scientific statements is further illustrated by the belief of some philosophers of science that the method of science involves universal doubt—Popper, for example, believes that scientific statements to be scientific must be testable and that we must always continue to doubt and test;[2] Bartley's comprehensively critical rationalism[3] formalizes the method of universal doubt by establishing universal criticism as the operational definition of rationalist identity.

Thus, truth and certainty are to be eliminated from the definition of scientific knowledge. We are left with belief and good evidence—hence, the claim that scientific knowledge is warranted belief. The only thing standing between scientific knowledge and knowledge in the weak sense of ordinary usage is therefore the strength of the evidence supporting scientific assertions.

To summarize the results of this section: Scientific knowledge consists in pointer readings which are classified into categories called laws and explanations. All laws and explanations resemble definitions in their formal character; they may also be regarded as testable predictions. Science calls its facts knowledge in the sense that scientific statements represent belief which is founded upon good evidence.

II. The Nature of Scientific Method

Science advances by beginning with ordinary common-sense observations; the means of observation are refined to promote accuracy and the observations are

[2]Karl R. Popper, *The Logic of Scientific Discovery*, Chapters 1 and 4.

[3]William Warren Bartley III, *The Retreat to Commitment*, Chapter 5.

interpreted formally into laws and explanations. These laws and explanations are then regarded as predictions which provide hypotheses, and the hypotheses are used to stimulate our search for data and to provide criteria for selecting relevant data from out of the mass of sense perception. The process outlined here is circular—no evidence is gathered and called evidence until our search is oriented by a hypothesis, and no hypotheses are long entertained unless they are suggested and supported by observations. Our hypotheses, taken all together, are the nets in which we catch our experiences.

Science makes progress by the successive improvement of hypotheses through the conjecture-refutation process—we strengthen hypotheses by eliminating their untenable aspects through suitable modifications in the light of experience, and we sometimes reject hypotheses or hypothesis systems (theories) entire.

In general, no hypothesis stands or falls alone. Networks of inter-related hypotheses are all involved every time an experiment is performed, and we must decide on other than empirical bases how the network is to be reorganized in the light of experience. Consider the following conversation in this respect:

P: (lying still on the ground): "I am dead."
Q: "You are not dead, and I shall prove this to you."
P: "Please do, for I should like to be alive."
Q: "Do you agree that dead people do not bleed?"
P: "I agree."
Q: "I have a knife and shall cut your arm off. If you bleed, that will prove you are not dead."
P: "Go ahead with the experiment."
Q: (after cutting off P's arm): "It is done. Your arm has been severed and you do bleed. Therefore, you are not dead."
P: "I agree that my arm has been severed and I do bleed. But I do not accept your conclusion that I am not dead. Rather, the experiment proves": (here P chooses one of these alternatives)
(a) "Some dead people do bleed—I was mistaken in accepting your generalization."
(b) "That blood you saw came from somewhere else."
(c) "Our logic is all fouled up."

There may be other alternatives which would enable P to maintain with consistency that he is dead. Perhaps (a) is the most reasonable alternative because it does not at all strain the limits of possibility. The important thing to see from this example is that a network of hypotheses is involved in the experiment, and we must choose on other than experimental grounds which hypotheses in the network will be maintained and which will be called experimentally falsified. No recourse is had to the results of other experiments designed to test specific hypotheses in the network, because any given experiment always has the character of this one in that any experiment calls into play whole networks of hypotheses. Ultimately our restructuring of the network involves a criterion or a choice which is not itself the sole directed result of experiment. This situation will be recalled subsequently when we discuss more directly the relationship between science and metaphysics. The dialogue presented here will also be further analyzed in section four.

To summarize the results of this section: By whatever means they are arrived at, the hypotheses of science orient our search for new data and remain standing or fall according to our interpretation of experiments which we believe test the hypotheses. No single hypothesis ever bears the full brunt of experimentation—rather, networks of hypotheses are involved in every experiment and we choose, on other than strictly empirical grounds, how the network will be reorganized with respect to truth and falsity in the light of experimental evidence.

III. THE STRUCTURE OF MATHEMATICS

Sections three and four are concerned with the structure of mathematics and its uses in science. Hence, it would seem appropriate to justify the inclusion of such topics in a paper on the integration of the disciplines. I hope to show that, although mathematics and science seem to be radically different in outward appearance and method, these subject areas show remarkable similarities. It is certainly no secret that scientists make extensive use of mathematics; indeed, many people speak about "math and science" in the same breath, as though these two subjects were really only one. We shall soon observe that mathematics is quite different from science—and yet, we shall see that science and mathematics fit together like hand and glove (which, incidentally, are quite unlike each other). The purposes of sections three and four are two-fold: (1) to explore how two quite different subject areas are in fact integrated, and thereby to get a glimpse at an actual integration of disciplines; (2) to further clarify certain aspects of our earlier discussion concerning the nature of scientific method.

If facts are the materials of the sciences, theorems are the materials of mathematics. In discussing the nature of mathematics, we must distinguish carefully between the way mathematicians go about their work and the refined structure which they seek to produce. A mathematician may very well be inspired by practical applications or problems in the sciences—the "logic" of mathematical discovery must surely include guesswork, insight, and practical motivation.

The ultimate aim of the mathematician, however, is the statement and proof of theorems. Every theorem in mathematics is reducible to if-then form, where the "if" includes the axioms and rules of inference adopted in the formal mathematical system being employed, and the "then" is the final conclusion actually stated in the theorem. Ultimately, the terms employed in stating a valid theorem can be reduced to primitive, undefined symbols in such a fashion that the lengthy string of undefined symbols constituting the "if" clause is identical to the string constituting the "then" clause.

Very few mathematicians have ever gone to the full extreme of establishing an alphabet of undefined symbols, listing rules for combining these symbols into "meaningful" strings, stating axioms in terms of these strings, and proving theorems by reducing them to strings of acceptable form.[4] Nevertheless, proofs

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[4]Russell and Whitehead provide such a formal system for arithmetic in *Principia Mathematica*. Kurt Goedel has proved by means of formal logic that arithmetic is essentially incomplete and that its consistency cannot be internally demonstrated. Loosely speaking, "arithmetic is consistent" is the only statement proved by Goedel to be formally undecidable; hence, his proof does not affect the general validity of formalistic methods for proving theorems.

of theorems are usually regarded as outlines presenting the major transformations which must be made in order to achieve validity, and behind every theorem and proof stands the formal deductive structure described here. In short, every theorem of mathematics is formally equivalent to the definitional tautology "x is x"; the value of a theorem consists in the validity which it accords to representing mathematical statements in forms which are more convenient or more immediately applicable.

IV. MATHEMATICS IN SCIENCE

Bertrand Russell once said that mathematics is the subject in which we never know what we are talking about nor whether what we are saying is true. The discussion of the last section should clarify his meaning. Mathematics deals in the transformation of symbols from one form into another, and is formally reducible to statements of the form "x=x." As such, mathematics has a formal structure which is independent of experience. Science, however, is concerned with "is" statements which report facts in the form "x is y." How is it, then, that something as empty as mathematics is such a valuable tool to the scientist? How is it possible for two such opposite endeavors to fructify each other? Perhaps our answers to these questions will point the way to the integration of the disciplines.

We recall that scientific reports of observations take the form "x is y," while laws, explanations, and predictions are logical structures which enable us to deduce observational statements of the form "x is y" from statements which classify collections of previous observations. We also recall that mathematics is composed of theorems which are ultimately reducible to tautological definitions of the form "x=x"; however, the tautology is usually concealed in the form "if A . . . then B." A and B may not be obviously related, but the logical system in which the theorem is proved enables us to reduce A and B to the same string of symbols, although the complete reduction is seldom carried out.

(1) Both mathematics and science therefore reduce to the logical structure of systems of definitions. Science says x is y, and thus classifies. Mathematics says x is x, expressed differently, and shuffles our way of saying x. Thus, mathematics and science reduce to logical structures. (2) At the level of actual usage, science reports empirical observations and mathematics exhibits a priori statements of if . . . then form, called theorems—the a priori statements of mathematics are neither true nor false but are logically valid, while the empirical observations of science are represented as statements about fact which are called true. The ultimate formal character of mathematics and science will be discussed first, followed by a discussion about their nature at the level of actual usage.

(1) In their ultimate formal characters, it is clear that both mathematics and science involve the use of logic—both draw upon the same notions of what is logical. Evidence is seen for this in the fact that the mathematical framework applies to science, so that we must be using common logical structures in both areas. Notice, for example, that we demand *consistency* in mathematics (among the hypotheses or axioms of the system) and in science (among the laws or explanations or hypotheses which constitute a theory). Whatever this "consistency" is, it seems that the notion is common to both mathematics and science and that the notion comes from sources broader than either subject area.

(2) At the level of ordinary usage, it appears that mathematics provides theorems of the form "if B then C," while science provides statements of the form "B is true" or "B has been observed." The conjunction of the statement "if B then C" with the statement "B is true" yields the conclusion "C is true." Therein lies the harmony between science and mathematics—the statement "C is true" is a mathematical deduction which can be interpreted as a statement of fact to be tested by science. Thus, mathematics provides a formal deductive structure which science fills with facts. Science chooses which deductive structure it wishes to adopt, and when and whether the axioms of that structure are satisfied in their factual interpretations.[5] Mathematics provides pre-fabricated deductive systems into which science inserts statements about observations and extracts statements about other observations which may or may not have been made.

The common structure and mutual interaction of science and mathematics are seen even more clearly when we realize that science accepts re-transmission of falsity from conclusions to hypotheses through the mathematical structure. In the example above, given the theorem "if B then C," and given the scientific observation "C is false," science accepts the falsity of statement B, based upon this mathematical property of if . . . then relations: if the conclusion of a valid deduction is false, then the premise is false. Notice that this re-transmission of falsity requires both that the deductive argument is valid and that the conclusion is in fact false. Granted both of these conditions, we may safely declare that falsity has been established for the premise.

Given an axiomatic system A and a theorem of the form "if B then C," and given the hypothesis or generalization "B is true" we *require* the truth of the fact-statement "C is true." The statement that C is true may be considered as a prediction, or deductive elaboration based on the statement "B is true." The truth of C is to be tested by scientific observation. If we now fail to confirm the truth of C but instead observe that C is false, one of the following conclusions is drawn: (1) B is false in point of fact (this would be re-transmission of falsity); (2) We were mistaken about C and indeed C is true—we must search more diligently; (3) A does not apply to this physical situation.

Notice that any one of these three alternatives is equally as consistent with observation as any other. I do not know how scientists actually choose among these alternatives in practice, but it should be clear that pointer readings and empirical observations alone cannot be a sufficient basis for decision. Probably (1) is the most frequent choice—it corresponds to experimental refutation or falsification of a hypothesis. (2) is perhaps almost as frequently chosen as (1), and corresponds to the claim that we must repeat our experiment because we are calling the results themselves into question. (3) corresponds to the claim that the logical or mathematical assumptions or axioms underlying our reasoning processes are not appropriate for the situation at hand. Alternative (3) is seldom used, but occasionally occurs: witness the dispute over whether Euclidean geometry or one of the non-Euclidean geometries is appropriate for scientific use (Newton chose Euclid and Einstein chose Riemann).

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[5]Henri Poincare, *Science and Hypothesis*, Chapter 3.

In this scheme, A is the system of mathematical or logical axioms, including rules of deduction and criteria for meaningfulness of strings of symbols. B may represent a hypothesis (which is to be tested by testing one of its consequences), a law, an explanation, or a prediction. C is usually a statement of fact concerning a particular situation. The reader will do well at this point to compare alternatives (1), (2), and (3) in this example with alternatives (a), (b), and (c) available to the "dead" man in the example discussed in the section on the nature of scientific method. In that example we were concerned only with scientific statements; in the present example we are discussing a system in which mathematics and science are mixed. However, even in "purely scientific" problems the logical structure of our reasoning processes plays the role of a system of axioms.

We note here that if the hypothesis B of the present example is equated with the generalization "dead men do not bleed" in the earlier example, we have a perfect correspondence between the alternatives of the two examples, such that (a) corresponds to (1), (b) corresponds to (2), and (c) corresponds to (3). However, if the hypothesis under test in the earlier example is the statement "P is dead," then to make the same correspondence between alternatives we must revise alternative (a) as follows: (a) "P is not dead, but alive"; (b) and (c) remain as before. Thus, to maintain that he is dead, P claims that the generalization "dead men do not bleed" was the hypothesis being tested, or else escapes by accepting alternative (b) or (c). If Q wishes to win the argument, he denies (b) and (c) and maintains the truth of the generalization while claiming that the hypothesis being tested is the statement "P is dead."

It is hoped that by studying these examples the reader will discover that, indeed, networks of hypotheses are involved in every experiment, and we choose on other than experimental grounds how the network is to be reorganized with respect to truth and falsity in the light of experimental evidence. In this section we have also seen how science uses the deductive framework supplied by mathematics.

V. METAPHYSICS IS ESSENTIAL IN SCIENCE AND INTEGRATES SCIENCE AND AXIOLOGY

Finally we have arrived at the point where we may reap the harvest from the crops cultivated in the earlier sections of this paper. In this section we shall discover how and why metaphysical considerations form an essential part of science, whether or not scientists are aware of such considerations. We shall also discover the ways in which metaphysical inquiry can play a major role in stimulating the advance of science. Finally, we shall notice a few of the problems which metaphysics must help us solve if we are to be successful in integrating science and axiology.

We have defined metaphysics as the study of the true nature of Reality, including the study of how such a study may best proceed. In section one we observed that scientific knowledge consists in pointer readings which are classified into categories called laws and explanations, and that science calls its facts knowledge in the sense that scientific statements represent belief which is founded upon good evidence. The discussion reported there between the scientist and the metaphysician should indicate clearly the difference between their points of view.

(1) Scientists are motivated to their work in the belief that they will discover regularities of nature which will enable them to understand and control nature. Thus, scientists are interested in discovering the truth about the way things are. However, for the sake of objectivity or precision or communicable meaningfulness, they confine their activities to observations of pointer readings and statements which classify these observations. They exclude as "unscientific" those "metaphysical speculations" which question the basis for scientific claims to truth or which attempt to discover whether there is a Reality which underlies and causes the phenomena observed by science but which is itself not capable of being studied through observations of pointer readings.

(2) Metaphysicians are motivated to their work in the belief that they will discover the true nature of Reality, or how we should go about making such discoveries. However, for the sake of generality or universal validity, they refuse to admit the claim that pointer readings are true indicators of Reality; and, even if they would agree that pointer readings are true indicators of Reality, they would claim that much more is needed besides pointer readings in order to justify that pointer readings are true indicators of Reality. To discover the true nature of Reality we cannot rely on pointer readings alone, and perhaps not at all.

It should be clear from this brief discussion that science and metaphysics are at war because each denies the validity of the other's approach or method of inquiry. Science refuses to discuss anything that cannot be studied through pointer readings, and metaphysics refuses to accept scientific claims as accurate when they are based solely on pointer readings. It should also be clear that science and metaphysics both share the same goal—the discovery and understanding of Reality.

In section two we discussed the nature of scientific method. The point made in that section was that science proceeds by generating and testing hypotheses. Although the source of the hypotheses may be of interest, the crucial part of scientific method is the testing of hypotheses by performing empirical observations. We then discovered that no single hypothesis ever bears the full brunt of experimentation—rather, networks of hypotheses are involved in every experiment and we choose, on other than strictly empirical grounds, how the network is to be reorganized with respect to truth and falsity in the light of experimental evidence. The discussion between the dead man and the butcher gave an illustration of how one network of hypotheses could be reorganized in several different ways in the light of one experiment.

The results of sections two and four provide grounds for questioning the adequacy of pointer readings as indicators of Reality. Not only are scientific constructs based on pointer readings subject to human limitations on ability to construct—there is also serious doubt about the source of authority employed by a scientist who claims that experiment X demonstrates that proposition Y has been falsified or corroborated. The generalized example in section four, and the specific example in section two, show that something other than publicly verifiable empirical data is involved in the process whereby scientists make claims concerning the interpretations of their experiments.

It therefore appears that an essential part of scientific research should be the study of how networks of hypotheses are to be reorganized with respect to

truth and falsity in the light of experience. Such inquiry would be metaphysical in the sense that it goes beyond the range of empirical verifiability or falsifiability; such inquiry requires that decisions be made concerning what kind of logic is most appropriate to the interaction between experiments and their associated networks of hypotheses. Since networks of hypotheses are also involved in non-scientific subjects like axiology, the study of network logic seems to involve all the disciplines, and the attempt to build generalized network logics could promote the integration of the disciplines at the theoretical level. It should be clear that metaphysical inquiry into the nature of Reality is essential if we are to build "correct" network logics or choose among several proposed logics which may all equally well fit all the various disciplines.

In studying the structures of mathematics and science, we observed that a vague notion of consistency is common to both. (1) A mathematical system is not considered valid unless its axioms are mutually consistent. Consistency of axioms usually is taken to mean that at most one of any pair of statement- and-contradictory-statement can be deduced from a consistent set of axioms. Thus we say a system of axioms is inconsistent if it is possible to derive or prove both a statement and its contradiction in ways labeled valid by the system. The circularity among "valid," "consistent," "contradictory," "proof," and "derivation" should be obvious here, and our vagueness concerning the notion of mathematical consistency remains unclarified. (2) Scientific systems or theories are not considered valid if it is possible to account for both the occurrence of a fact and the non-occurrence of a fact under the same conditions in theory. Thus we say a theory is "refuted by the facts" in case the theory predicts or explains the opposite of what is observed, and we do not seriously consider theories which are shown to be compatible with any eventuality.

Whatever this "consistency" is, it certainly includes the notion that statements p and not-p are not both simultaneously admissible. Perhaps it would be the very definition of madness to question the unquestioned assumption that no theoretical construct or axiomatic system can be "correct" unless it is at least consistent. Yet, without a rational defense of the consistency criterion for acceptability, we cannot claim that our theories our rational. To my knowledge there is no clear formulation of the consistency criterion and there is no rational defense of the criterion which does not assume the criterion to begin with. Perhaps the criterion is too narrow, so that we exclude valuable theories. It appears that metaphysical inquiry is needed here.

An important by-product of section four is the observation that science and mathematics fit together in much the same way as hand and glove—mathematics provides a formal deductive structure which science fills with facts. This integration between science and mathematics exists in spite of their outward difference in appearance. Mathematics is a subject which is not concerned with experience and which cannot be studied by means of pointer readings; science is concerned entirely with pointer readings and constructs which classify them.

By making a study of two disciplines which are obviously connected in actual practice, we have explored how it is that they are integrated in their theoretical foundations. In a similar manner it is to be hoped that other disciplines which are inter-connected in actual practice can be integrated through theoretical study.

Discovering the integration of disciplines which are clearly related may help us learn how to integrate those disciplines which are less clearly related. The integration of science and axiology will require vast effort, and could be helped along the way by smaller-scale integrations within each general area.

Thus far in this section, we have clarified and elaborated the issues raised in earlier sections concerning the relationship between science and metaphysics. The following problems have been proposed as examples of how metaphysical inquiry can contribute directly to the advance of science, and is necessary for the theoretical foundation of science: (1) What is the logic of hypothesis networks and their interaction with experiments? (2) What is the meaning of "consistency" and is consistency appropriate as a necessary condition of mathematical and scientific acceptability?

In the eventual integration of the scientific and axiological areas, both of these problems will have to be expanded: (1) what must be the character of universal network logics applicable to all the disciplines? How can we construct universal network logics consistent with the network logics of all the various disciplines and broad enough to "include" them all? (2) What will an expanded notion of "consistency" look like? How can we obtain a generalized notion of consistency which is consistent with and includes all the notions of consistency in mathematics, science, ethics, aesthetics, etc.? (3) In addition to these two problems, we must face the determinism-indeterminism issue and resolve it in a way satisfactory to all the disciplines. Thus, science assumes by its very methods the universal applicability of cause-effect (the Uncertainty Principle says only that we cannot measure the cause-effect relationship with complete accuracy—this strengthens the demand for metaphysical explanation), while axiology and especially moral theory assume the freedom of man's action from total external constraint.

No doubt, other problems exist in any attempt at theoretical integration of the disciplines. Certainly the above three problems will be involved in the integration of science and axiology. By way of concluding remarks, I shall offer the following four points:

(1) Whether or not scientists realize the inter-relationship between science and metaphysics, the two areas of inquiry are closely connected. Science can make progress without paying attention to metaphysics, but does so at the risk of building on hollow foundations which someday might crumble under the weight of the scientific edifice. Furthermore, the technological usefulness and practical fruitfulness of science may continue to provide civilization with increasingly better means of living, but science without metaphysics will suffer from shallowness of understanding and appreciation of the universe.

(2) Metaphysical inquiry provides a rich source of speculation concerning the nature of Reality, and such speculation may lead to insight or beliefs which will provide new scientific theories. In science it is not particularly important where a theory comes from—the important thing is whether a theory stands up to test. Whether or not well-corroborated scientific theories correspond to Reality, they do provide technological advance, and metaphysics can have no cause for complaint if science uses metaphysical speculation to generate scientific theories.

Elevating scientific theory to the status of metaphysical description of Reality is beyond the capacity of scientific method, but metaphysical speculation may produce insight leading to valuable scientific theory. Thus, 200 years ago the theory that matter is composed of atoms, or the theory that matter is some kind of dense energy, would have been called metaphysical.

The simple mechanical models we use to explain to children the complex scientific theories about the structure of matter or the nature of the space-time warp are illustrative of the aid to understanding and further inquiry which metaphysics can supply. Certainly these models do not in any sense represent Reality nor are they scientifically accurate, but they do supply a temporary means of understanding the first approximation to scientific truth while continuing the process of gaining a better refinement. The use of temporary shelters along the wilderness trail to the mansion on top of the hill characterizes both childhood learning and scientific progress.

(3) If a fisherman uses a net with a mesh-width of three inches, he may conclude that there are no minnows in the sea.[6] Even if his net cannot be refined to a smaller mesh-width due to the nature of the building materials, he will profit by making the observation that indeed his net is limited by its very nature to catching fish longer than three inches. For with this knowledge he will not claim there are no small fish. Rather, he will recognize the limitations of his net and seek other ways of accounting for the mysterious "fact" that three-inch fish come into existence three inches long, without having grown through smaller sizes first. His "meta-net" theories may even enable him to learn to build fish-hatcheries and thereby avoid the capriciousness of nature. Thus science, by learning its limitations, may learn to make use of other means of obtaining progress in areas of interest to science.

However, if the net has no inherent limitations on the size of the mesh-width, a knowledge of the fact that the mesh-width is three inches and that this limits the kind of catch the fisherman can make will encourage the fisherman to refine his net. By studying the possible limitations on human knowledge, the processes used by the mind in organizing experience, and the nature of scientific method in comparison with the methods of other disciplines and the reality revealed by other disciplines, the scientist may learn how to improve his reasoning processes and his technology of discovery.

(4) The Reality which is "out there" is the ultimate source of all that we observe and all that we experience. In studying that Reality, by whatever means, we are studying the ultimate subject matter which science aims to produce. Such study is simultaneously the study of what is possible, what is necessary, and what range of choice is available to man. Hence, metaphysical inquiry is the ultimate goal and subject matter of both scientific studies and studies of value (such as ethics and aesthetics). Therefore, metaphysical inquiry provides a unifying bond between science and axiology. Knowledge that this bond exists means that the integration of the disciplines is possible, and study of the bond may help us understand and teach the disciplines in an integrated manner, thereby providing a unified world view.

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[6]The metaphor of the fish net was suggested by Arthur S. Eddington, *The Philosophy of Physical Science*, Chapter 2.